X-File 4-11.61xx

Guide to Employing Renewable Energy and Energy Efficient Technologies

Marine Corps Warfighting Laboratory (MCWL)

U.S. Marine Corps

DISTRIBUTION A: Approved for public release; distribution unlimited

Report Documentation Page						*Form Approved OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.						
1. REPORT DATE **SEP 2012**		2. REPORT TYPE				3. DATES COVERED **00-00-2012 to 00-00-2012**
4. TITLE AND SUBTITLE **Guide to Employing Renewable Energy and Energy Efficient Technologies**						5a. CONTRACT NUMBER
						5b. GRANT NUMBER
						5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)						5d. PROJECT NUMBER
						5e. TASK NUMBER
						5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Marine Corps Warfighting Laboratory (MCWL),3255 Meyers Ave,Quantico,VA,22134**						8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)						10. SPONSOR/MONITOR'S ACRONYM(S)
						11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**						
13. SUPPLEMENTARY NOTES						
14. ABSTRACT						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**57**		

X-File 4-11.61xx

Guide to Employing Renewable Energy and Energy Efficient Technologies

NOTE
Unless this X-File states otherwise, masculine nouns and pronouns refer to both men and women.

NOTE
This and all of the X-Files are available on SharePoint to authorized personnel using the approval process entered via:
https://ehqmcsupport.usmc.mil/sites/mcwar/default.aspx
X-Files are also available on the MCWL SIPRnet Website.

NOTE
This X-File is in MS Word *"Book fold"* format per the "page setup" choice in the *"File"* drop down menu at the upper left of your taskbar. Thus, it is ready to print out perfectly as a booklet as long as you have a duplex (two-sided) printer. When setting up for printing - do NOT select *"Booklet"* in the printer dialogue box - and DO select *"flip on short edge"* for the print.

U.S. Marine Corps

USE of Special Text Boxes

WARNING
A procedure, practice, or condition that may result in injury or death if not carefully observed or followed.

CAUTION
A procedure, practice, or condition that may damage equipment if not carefully observed or followed.

NOTE
A procedure, practice, or condition that is essential to emphasize.

.

Marine Corps Warfighting Laboratory
Marine Corps Combat Development Command
3255 Meyers Avenue
Quantico, Virginia 22134-5069

10 September 2012

FOREWORD

1. PURPOSE: This X-File gathers, organizes and synthesizes knowledge gleaned by the Marine Corps Warfighting Laboratory utilizing lessons learned from the Experimental Forward Operating Base (ExFOB) process, and from limited experimentation, pre-deployment training and post deployment reports. It is in a format that can be quickly read and easily transported—in the cargo pocket of the utility uniform—so easy-to-use information is immediately available to all levels of command.

2. SCOPE. This X-File consolidates knowledge on technologies that were evaluated during the ExFOB process in close cooperation with the Commandant's *Expeditionary Energy Office (E2O).* These technologies have proven to reduce the logistic footprint of Marines operating from austere operating locations in Afghanistan.

a. All of the systems described in here can be found in open access sources.

b. We have outlined the capabilities of the technology and clarified how it could be employed.

c. We do not replace any Government-issued Technical Manuals nor is this knowledge intended to replace any existing tactical warfighting fundamentals.

d. Our goal is to optimize potential use of the technologies in conjunction with established Marine Corps doctrine, orders, and higher level policy guidance.

3. HANDLING INSTRUCTIONS. This X-File is approved for public release; distribution unlimited.

4. SUPERSESSION. None.

5. FEEDBACK. We want to know how units and individuals use this X-File. Please submit any user feedback and suggestions to the above address or submit recommendations electronically to the X-File link on the MCWL SharePoint site. Authorized users can request an account for this site at:

https://ehqmcsupport.usmc.mil/sites/mcwar/default.aspx

6. CERTIFICATION. Reviewed and approved this date.

M. R. Wise
Brigadier General, USMC
Commanding General

Contents

Section 1 – Introduction 1
Commander's Intent 1
Focus 2
USMC Expeditionary Energy Objectives 2
Goals of this X-File 2
Section 2 – Implementation 3
Overview 3
MAGTF Power Demand 3
Strategic Concepts 3
Implementation 4
Section 3 – Energy, Power, and Planning 6
Overview 6
Energy and Power 7
Calculating Power Demand 7
Table 1 COC Standard Equipment 7
Table 2 USMC Power & Energy Quick Card (TQG) 9
Figure 1 Squad Employment of SPACES 10
Figure 2 Platoon Employment of GREENS 11
Section 4 – Solar Energy Basics 12
Photovoltaic (PV) Systems 12
Figure 3 Azimuth vs. True South 13
Figure 4 Tilt Angle Determination 14
Solar Panels, Modules and Arrays 15
Figure 5 Solar Panel 15
Section 5 – Batteries 16
Overview 16
Battery Management 18
Concept of Operations 19
Figure 6 Power Practices and Procedures 20
Section 6 Radiant Barrier Blanket (RBB) 21
Overview 21
Figure 7 RBB Installed in a Base-X Shelter 21
Capabilities 21
Components 22

Table 3 RBB Components *22*
Operational Principles *22*
Section 7 – SPACES **23**
Overview *23*
Capabilities *23*
Table 4 Physical and Electrical Properties *23*
Components *24*
Figure 8 Major Elements of SPACES 24
Operational Principles *24*
Figure 9 Major Elements of SPACES 25
Input Designs / Receiving Power 25
Section 8 – GREENS **27**
Overview *27*
Capabilities *27*
Table 5 Configurations *28*
Components *28*
Figure 10 GREENS QuadCon Pack up 28
Charge Control Box (CCB) *29*
Figure 11 CCB Front View 29
CCB Capabilities 29
High Energy Lithium Batteries (HELB) *29*
Figure 12 High Energy Lithium Batteries 30
Integrated Solar Panel Case Assemblies *30*
Figure 13 GREENS Interconnect Cables 31
Figure 14 DC Power Distribution Kit 32
Power Management System *32*
Figure 15 Power Management System 33
Figure 16 GREENS Process Nodes 34
GREENS Supporting HIMARS Employment *35*
Figure 17 GREENS Supporting HIMARS 36
Figure 18 an FCS Hookup at the Vehicle 37
Figure 19 Vehicle Battery Box 37
Section 9 – Tactical Shelter Lighting **39**
Overview *39*
Figure 20 LED Master Controller 39
Capabilities *40*
Figure 21 LED Operating Mode Capabilities 40

Components 40
Table 6 LED Physical Specifications............................ 41
Operational Principles 41
Table 7 Electrical Operating Specifications................. 41
Appendix A – Acronyms 42
Appendix B – Glossary.. 43

Section 1 – Introduction

To maintain our lethal edge, we must change the way we use energy. The current and future operating environment requires an expeditionary mindset geared toward increased efficiency and reduced consumption, which will make our forces lighter and faster.

JAMES F. AMOS
General, U.S. Marine Corps
Commandant of the Marine Corps

Knowledgeable employment of renewable energy technology currently available to the Marine Corps can reduce a unit's demand for outside logistical support as it conducts combat operations from austere and remote locations. Minimizing the logistical support to forward operating units can enhance the ability of the Marine Air Ground Task Force (MAGTF) to function throughout the range of military operations.

Commander's Intent

To identify emerging renewable energy technologies and to gather, organize and synthesize knowledge of some existing practices that show potential to increase combat effectiveness and reduce the logistic footprint of Marines operating in austere conditions. We want to inform Marines at all levels about the capabilities of the technology and clarify potential use of the technologies in conjunction with established Marine Corps doctrine, orders and emerging higher level policy guidance.

END STATE
A concise compendium that accurately outlines emerging policy and informs the operating forces of available technology that has demonstrated potential to enable dispersed combat operations and decreases the demand for outside logistical support.

Focus

These are proven technologies that have reduced the MAGTF logistic footprint. This X-File combines knowledge of several different systems and technologies with which the unit could deploy. However, the key to successfully adapting any technology is the training provided to our Marines. This X-File aims to guide the development of more permanent training and education to successfully deploy renewable and energy efficient technologies.

USMC Expeditionary Energy Objectives

The objectives set forth in the Marine Corps Expeditionary Energy Strategy Implementation Plan of March 2010 are:

- Forging an ethos that equates energy efficiency with combat effectiveness
- Increasing energy efficiency of expeditionary systems
- Increasing the use of renewable energy in battlefield operations

Application of these approaches will increase operational effectiveness *and* reduce the risk to Marines. By increasing self-sufficiency and lightening the individual and MAGTF load, the MAGTF will shrink its threat-exposure, as created by logistical demands, and increase maneuverability at all levels. These improvements are imperatives to future Marine operating concepts and will save lives.

Goals of this X-File

- Outline emerging Marine Corps policy that aims to
  - change the way the Marine Corps employs energy
  - increase combat effectiveness
  - reduce our need for logistics support ashore
- Inform all levels of command regarding the strengths and limitations of some technologies that can be used to implement Marine Corps Policy
- Clarify and simplify system descriptions and consolidate them in a single highly portable document

Section 2 – Implementation

Overview

More than 60% of our logistics is dedicated to fuel and water resupply. A recent study of resupply in Afghanistan found that for every 50 convoys of fuel and water, one Marine or Civilian contractor was killed or wounded in action. Clearly, reducing our need for "liquid logistics" is an operational imperative.

Employing renewable and energy efficient technologies increases combat effectiveness of the MAGTF and reduces risk to our Marines. In addition, employing these technologies and modifying behavior will reduce the weight of the MAGTF and the burdened carried by individual Marines.

MAGTF Power Demand

Future command and control (C2) systems will continue to increase the need for man portable and mobile power sources along with storage batteries, both rechargeable and disposable. Therefore, finding a way to provide all elements of the MAGTF with alternative sources of power for communications equipment, computers, and other electronic equipment can substantially reduce the size of resources dedicated to provide energy and power to all elements of the MAGTF.

- See Tables 1 and 2 for power demand / planning factors

Strategic Concepts

Current and future Marine Corps plans are focusing on units that are dispersed throughout the battlespace as they execute the emerging Enhanced MAGTF Operations (EMO) concept. This mandates that units shall operate within these policy boundaries:

- Operational Plans shall incorporate renewable energy and energy efficient technologies that reduce fiscal costs, logistical support assets and hazardous material handling capabilities
- Future C2 systems shall reduce/replace the need for battery, man portable, and mobile power sources
- MAGTFs shall be provided with alternative sources of power for communications, computers and other electronic equipment

Expeditionary Energy Employment Imperatives

- Achieve resource self-sufficiency on the battlefield
- Reduce energy demand in platforms and systems
- Reduce power generating support requirements
  - to include mobile power generators and batteries
- Reduce the overall footprint in expeditionary operations

Implementation

This X-File compiles some current renewable energy and energy efficient technologies that provide portable alternative power sources to operate equipment in mobile, tactical or remote environments. They also provide work space cooling/heating applications. These technologies accomplish the following:

- Harvest solar energy
- Enable a workable battery management plan
- Provides an Environmental Control Unit (ECU) or heater capacity needed to cool or heat the shelter
- Provides an additional thermal barrier, increasing the shelter's insulation factor
- Utilizes LED lights
  - longer life, lower power consumption than fluorescent bulbs
- Capability to match load to power source planning

A typical mission profile for this equipment shall consist of a family of alternative power sources and energy efficient technologies to support currently powered equipment. The renewable energy and energy efficient technologies shall be used

in garrison or in a field environment. It shall be capable of being operated under inclement conditions with no additional supplemental protection other than what is provided to the communications equipment, computers and other electronic peripheral equipment.

The renewable energy and energy efficient technologies shall also be capable of replacing batteries in garrison for operator preventive maintenance services and operator training. During field communication exercises and deployments the technologies shall reduce the reliance on batteries and fuel-powered generators.

Renewable and energy efficient technologies shall provide a suite of alternative power sources to provide portable electric power to energize communications equipment, computers and other electronic peripheral equipment in fixed base, tactical, austere, and shipboard operations under both administrative and tactical conditions. This capability shall provide enhanced power generation and power storage capabilities to operating forces that, when coupled with maturing power management practices, shall significantly reduce the costs and logistics burdens associated with reliance on batteries and fuel powered generators as the primary power source for communications-electronic equipment.

This guide informs all levels of command on enablers to change the way the Marine Corps employs energy and resources to increase combat effectiveness and reduce our need for logistics support ashore.

Section 3 – Energy, Power, and Planning

Overview

The most effective way to improve efficiency is to reduce demand. In order to employ renewable energy systems effectively, every Marine must take an active role in conserving energy storage through the disciplined management of electrical loads. In short, we must adopt a “Spartan” mindset.

To employ renewable energy effectively, Marines must first understand the power they require to accomplish the mission and the capabilities and limitations of renewable energy harvesting, storage, and distribution tools at their disposal.

Traditionally, Marines plan power based continuous peak loading from every piece of equipment that is anticipated. Using this load, generators are then typically scaled to include a 20% margin above this “peak of the peaks” load when, in fact, current program of record (POR) generators are capable of running at rated load and absorbing transient loads above their rated load without harm to the system. The consequence of this approach to power planning is that it forces the deployment of larger generators than necessary, increased fuel consumption, and wasted fuel. A secondary consequence is that these over-sized generators when run well below their rated load for extended periods of time, become more susceptible to failure when loads are increased. They also require maintenance that could have been avoided. Further, using the “peak of the peaks” approach increases the likelihood that renewable energy sources are ruled out and opportunities to reduce battlefield fuel consumption are missed.

Renewable energy is most effective when Marines understand their <u>total continuous need for power</u> and the possible individual peaks

of high power demand systems like microwave ovens, coffee pots and environmental control systems. Marines must also understand their energy storage capacity and the techniques and procedures for managing stored energy to meet continuous power needs.

Energy and Power

- Energy is defined by kilowatt hours (kWh)
- Power is defined by kilowatts (kW)

Calculating Power Demand

Tables 1 and 2 array some common mission essential equipment and the power required to operate that equipment in a USMC Combat Operations Center (COC) in austere conditions.

Item	Quantity (In Use)	Current (A)	Voltage (V)	Indiv Pwr (W)	Collective Pwr (W)
Laptops (SIPR)	17	0.42	118	41	697
Monitor (22”)	2	0.54	118	63	126
Projector	1	2.2	118	260	260
Smart-Board	1	0.03	118	4	4
Printers (idle)	2	0.08	118	10	20
Cisco Phone	1	0.03	118	3	3
Cisco SIPR Switch*	3	6	116	69	207
Jupiter Video Processor	1	2.1	117	176	176
LED Lights (Bright Setting)	8	0.21	119	25	200
***not metered: Empirical data**				**Total**	**1693**

Table 1 COC Standard Equipment

Add all the power required to run equipment shown in the Tables. If this equipment is on for one hour it would require x kWh.

Equipment	Average Power (W)	Peak Power (W)	Fuel Burn Rate (gal JP-8/day)
*Laptop	35	50	0.1-0.13
*Toughbook	35	50	0.1-0.13
*LED Light	25	27	0.07-0.09
*Jameson Light	75	75	0.20-0.28
*Motorola Battery Charger	50	200	0.14-0.18
*Soldier Portable Charger	50	300	0.14-0.18
*PRC-152 Charger	10	100	0.03-0.04
*GBOSS Tower	500	3,000	1.36-1.88
*GBOSS Heavy (w/2 40” LCDs)	961	800	2.6-3.6
*Coffee Pot	45	975	0.13-.017
*Microwave	15	1,650	0.04-0.06
*VRC-110 w/Blue Force Tracker	165	440	0.44-0.62
*40” LCD	110	130	0.30-0.41
*40” Plasma	250	300	0.68-0.94

Equipment	Average Power (W)	Peak Power (W)	Fuel Burn Rate (gal JP-8/day)
*PRC-150	57	375	0.15-0.21
*B0001 ECU Heat/Cool	3,000/3,000	-	8.8/8.8
*B0002 ECU Heat/Cool	6,500/6,500	-	19/19
*B0003 ECU Heat/Cool	5,000/3,000	-	14.5/8.8
*B0004 ECU Heat/Cool	7,500/7,500	-	22/22
*B0005 ECU Heat/Cool	9,600/9,600	-	28/28
*B0006 ECU Heat/Cool	9,600/9,600	-	28/28
*B0008 ECU Heat/Cool	11,000/9,500	-	32/28
*B0010 ECU Heat/Cool	14,000/14,000	-	41/41
*B0012 ECU Heat/Cool	5,000/5,000	-	14.5/14.5
*B0014 ECU Heat/Cool	9,600/9,600	-	28/28
*B0074 ECU Heat/Cool	2,500/2,500	-	7.3/7.3
*B0075 Reefer	1,900	3,300	5.5
*Wireless Point-to-Point-link (WPPL)	484	490	1.41
PRC-152	4	25	5

Table 2 USMC Power & Energy Quick Card (TQG)

NOTE
For all equipment marked with the asterisk (*), the number of batteries consumed per day may increase in weather below 32°F.

Squad Employment of SPACES

Figure 1 can be used to determine short duration missions for powering various tactical radios and personal electronics while recharging a BA-2590. For example, one SPACES panel (in optimal conditions) can recharge a BA2590 in 8-12 hours; two SPACES panels 6-8 hours while providing on-demand power for the tactical radio. See Section 7 for detailed SPACES capabilities.

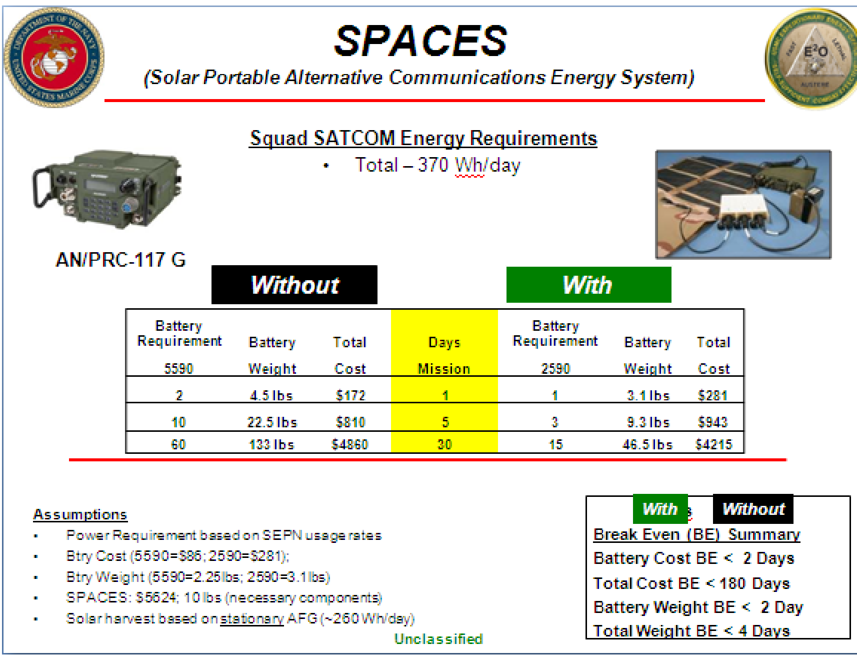

Figure 1 Squad Employment of SPACES

Platoon Employment of GREENS

The GREENS system is not as sensitive to optimal conditions as SPACES; as it can harvest energy in less than ideal conditions and has an array of energy storage banks. Using Figure 2 as example, the GREENS system produces more energy than the listed

equipment will use; excess energy is stored for future use. See Section 8 for detailed GREENS capabilities.

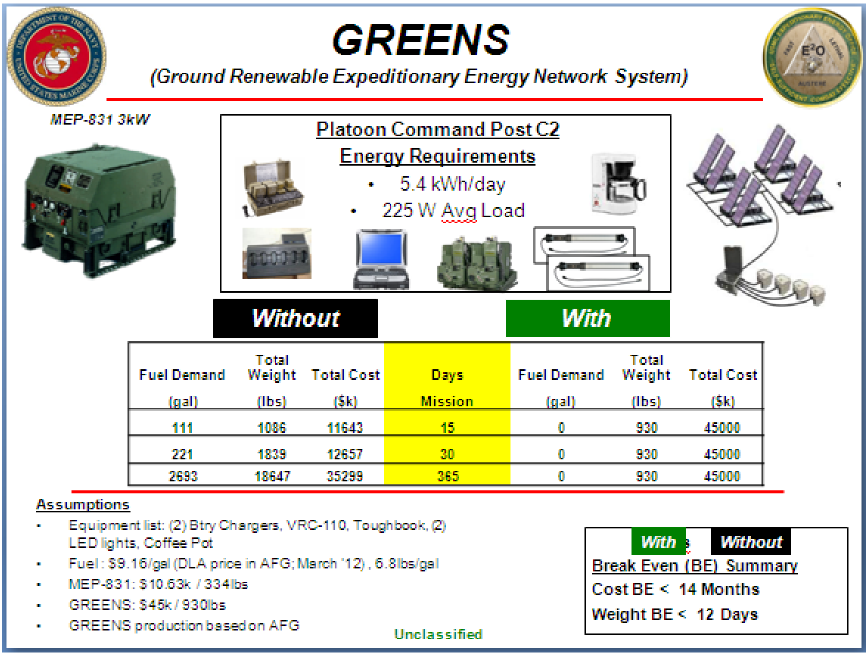

Figure 2 Platoon Employment of GREENS

To calculate power production of GREENS go to: http://mapserve3.nrel.gov/PVWatts_Viewer/index.html

Section 4 – Solar Energy Basics

Photovoltaic (PV) Systems

PV systems are designed to harvest energy directly from sunlight. They include solar panels, batteries, power control electronics and accessories that enable power applications.

Solar Insolation Considerations

Solar insolation is the amount of solar radiation energy received on a given surface area during a given period of time. It is used as a measure of how much of the sun's energy is striking a location on the earth's surface over a given time and, hence, is available for harvesting. It is typically denoted as Watts per hours per square meter. On a clear day with the sun rays directly perpendicular to a surface, the total instantaneous power density (solar irradiance) of the sun's rays is about 1,000 watts per square meter.

PV modules harvest solar rays and produce direct current (DC). These modules are most productive when the panels face directly into the sun (i.e. are as close to perpendicular to the sun's rays as practical). Two factors affect the angle at which the sun's rays strike a solar panel:

- Direction / azimuth
- Tilt angle

Diffuse and Direct Solar Radiation

As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by:

- Air molecules
- Water vapor
- Clouds
- Dust
- Pollutants
- Forest fires
- Volcanoes

This is called <u>diffuse</u> solar radiation.

The solar radiation that reaches the Earth's surface without being diffused is called direct beam solar radiation. The sum of the diffuse and direct solar radiation is called global solar radiation. Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days.

Azimuth is the horizontal direction expressed as the angular distance between the direction of a fixed point and the direction of the object. In PV terms, it is the sun's apparent location east and west of true south (northern hemisphere) or true north (southern hemisphere). See Figure 3.

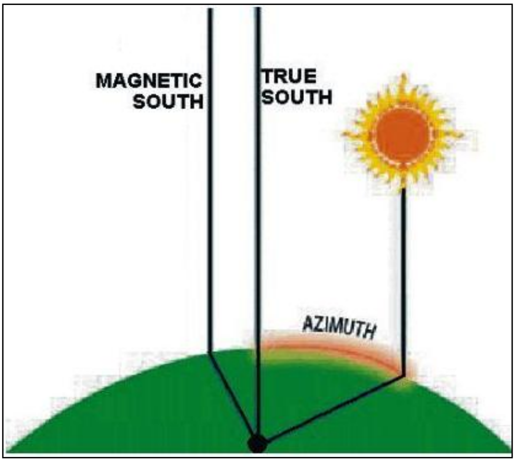

Figure 3 Azimuth vs. True South

To optimize power output in most areas, align the fixed panels to face true south (not magnetic south) in the northern hemisphere and true north in the southern hemisphere.

Depending on the location, it can be beneficial to compensate for environmental effects. For example; if the location is in a valley with mountains to the west, it may be more beneficial to face the solar panels a little to the east and collect extra power during the morning. This will compensate for losing power in the afternoon from the shade caused by the mountains.

NOTE
If the environmental effects and proper azimuth are uncertain, the system should remain facing true south (in the northern hemisphere) or true north (in the southern hemisphere).

Tilt angle refers to the PV panel's vertical angle relative to the ground. Optimum tilt angle is a function of the sun's elevation relative to the horizon at the location of interest on the earth at any given time. Once a panel aligned to the proper azimuth, the tilt angle is determined. The two factors that determine the optimum tilt angle are: Latitude and Time of year.

For a fixed solar panel system, a general year round rule is to set tilt angle equal to the latitude. For example; at the north and south poles, the latitude will equal 90°. At 45° North or South latitude the tilt angle of the solar panels should be 45°, and at the equator the solar panels should be laid flat. Figure 4 summarizes this. If the solar panels have an adjustable tilt angle, adjust as follows:

- Winter – latitude plus fifteen degrees
- Summer – latitude minus fifteen degrees

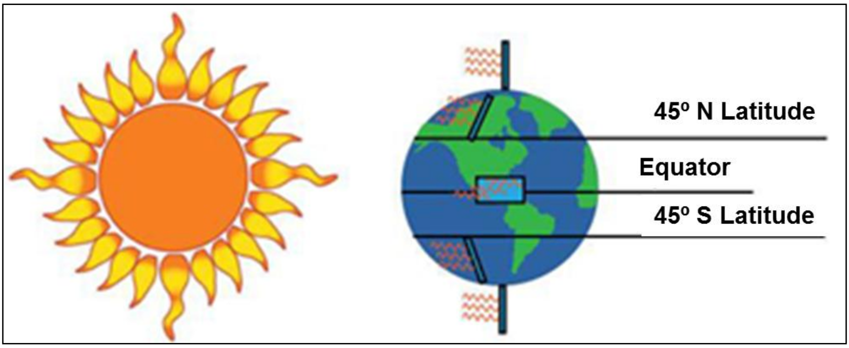

Figure 4 Tilt Angle Determination

Solar Panels, Modules and Arrays

Solar modules are made up of a number of solar cells linked in a *solar panel* through series and parallel circuits. Figure 5 shows a solar panel.

Figure 5 Solar Panel

Most *solar modules* produce a relatively low amount of voltage and amperage. Depending on load requirements, multiple modules can be used together, creating a *solar array*, to reach the desired energy production. This allows tailored solar production which can match the type of load requirements that exist.

Solar Energy Storage

Batteries store electrical energy. Within solar systems, batteries store harvested energy for use as needed to include providing power during limited light and no-light conditions. It is important to know what types of batteries are in use. Improper use can severely damage batteries, reducing overall lifespan and power output. Like PV cells, batteries can be connected in series to increase voltage, or in parallel to increase current.

WARNING

Solar systems are silent energy systems. Always assume live voltage is present.

Section 5 – Batteries

Overview

Primary Batteries

The main sources of power for Marine Corps communications equipment are primary batteries; most notably the Lithium-Sulfur Dioxide battery BA-55908/0. Primary batteries are non-rechargeable, one-time use batteries. Increased operational tempo and unexpected production shortfalls have severely reduced the availability of high demand, high-use primary batteries. Units cannot continue to rely on primary batteries as the sole source of power for their communications equipment.

Battery Capacity

No battery is 100% efficient. A 100 Amp-hour (Ah) battery is not likely to produce one amp for 100 hours. Many factors can affect battery capacity, including type of battery, the rate of discharge, depth of discharge, temperature, and age of the battery. These factors vary with battery types as discussed below.

Rechargeable Batteries

Rechargeable batteries are the only option for use with PV systems. While any type of rechargeable battery may be used, lead-acid and alkaline batteries are most commonly used in solar systems. Lithium ion batteries are also becoming more frequent in solar applications. While any rechargeable battery can do the job, deep cycle batteries perform best in PV systems.

WARNING

Batteries are potentially the most dangerous of PV system components. Ensure that the person handling them is properly trained and uses all personal protective equipment (PPE) designed for electrical systems.

Deep Cycle Batteries

Every time a battery is drained to any amount and then charged again, it is called a cycle. Depth of discharge refers to how much capacity is withdrawn from the batteries before it is charged again. Solar systems often require a battery to discharge small amounts of current over long periods and to recharge under variable conditions. A deep cycle battery is designed for this sort of application. The care and use of a deep cycle battery is the same regardless of its chemical makeup.

> **NOTE**
> **A car battery is not considered deep cycle. It is designed to be used in short bursts of energy, to start the car, then immediately recharge. You could use a car battery in solar systems but its life cycle would be significantly reduced.**

Another factor to consider is the rate and depth of discharge. If a battery is discharged quickly, it will not have as much capacity as if it were drained at a slower rate. For example: A battery is discharged over 24 hours and produces 180 Ah of capacity. That same battery discharged over 8 hours only produces 154 Ah of capacity.

Most deep cycle batteries used with PV systems will be designed for regular discharges of 40 to 80 percent. Battery life will be directly related to how deep the battery is cycled. Drawing deeper into a daily cycle will reduce the overall lifespan of the batteries.

For example; a battery that regularly cycles at 50% until it is charged again will last about twice as long as batteries that cycle to 80% discharge before they are charged.

Rechargeable batteries are labeled with information about the rate and depth of discharge and the battery’s expected total life span. This information is used to determine the amount of capacity the battery bank needs, the size loads to employ, and length of time a battery bank will last.

Effect of Temperature on Batteries

Batteries are very sensitive to temperature.

- In hotter temperatures (100° or more)a battery can be expected to have half its normal life—but, its capacity will increase
- In colder temperatures (32° or less) a battery may only achieve 60%-80% capacity—but its total life will increase

> **NOTE**
> **It is best to keep batteries in a moderate climate (75°-80°) to operate at expected values. As a rule, once the maximum capacity of the battery bank is less than 20% of its rated capacity—replace it**

Tips to Increase Battery Life

- Do not drain lead acid batteries more than 50%
- Lithium ion batteries may be cycled as deep as 100% rated capacity, always refer to manufacture recommendations.
- Discharge the battery banks gradually
- Avoid high loads drawing too much power over short periods
  - this is not true for high energy lithium batteries; e.g. GREENS[1] batteries
- Operate and store batteries in a moderate temperature

Charge Controllers

Charge controllers regulate the voltage and current coming from solar panels into the battery. They adjust for variable solar panel/array output in response to the variable solar radiation received by the panel/array.

Inverters

Inverters convert the DC output from a battery bank or PV system into alternating current (AC).

Battery Management

Primary battery conservation is intended to ensure long-term availability of primary batteries for those units and missions that have no other option to power their equipment. This entails

[1] See Section 8 in this X-File for discussion of GREENS.

shifting from primary batteries as the first choice for powering equipment to being the last choice.

Concept of Operations

Leverage the use of power sources available for units and missions instead of primary batteries. Use the following guidelines:

- Reserve the use of primary batteries where they are the only practical option
- If AC power is available, use AC energized power adapters, power supplies, or AC powered power sources/converters to power the equipment
- If DC power is available, use DC energized power sources/converters to power the equipment
- If neither AC nor DC power is available, and the mission can be accomplished using secondary batteries (i.e., rechargeable batteries), then use rechargeable batteries
- Conduct recharging operations during or after use
  - depending on mission duration
- Recommended use of rechargeable batteries is <u>four</u> <u>to</u> <u>one</u>
  - four batteries for each piece of battery powered equipment
    - one in the equipment
    - one for back up
    - one in transit to the equipment
    - and one on the charger
  - some units have successfully used a three to one ratio

Reduce reliance on primary batteries as the sole source of power by establishing practices and procedures to conserve primary batteries for the use in equipment applications to those missions where they are the only practical option. Figure 6 arrays options.

First estimate peak and average kW demand of equipment. Use factors arrayed in Tables 1 and 2.

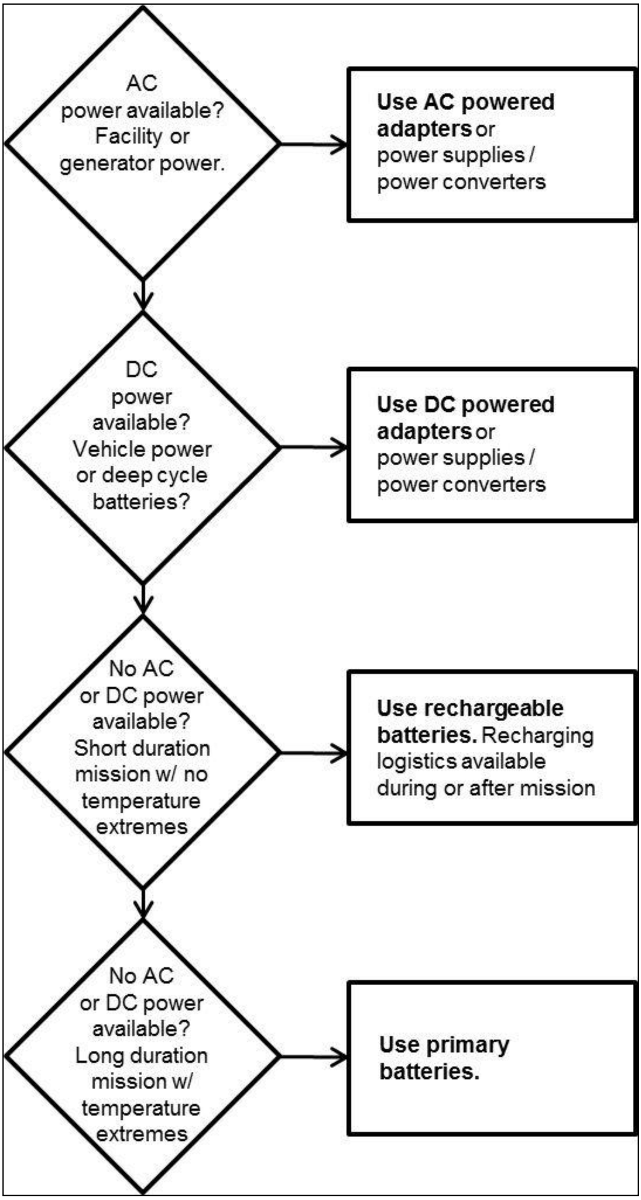

Figure 6 Power Practices and Procedures

Section 6 Radiant Barrier Blanket (RBB)[2]

Overview

The RBB is an expeditionary shelter accessory used in the BASE-X 100, 200, and 300 series shelters. It creates an additional thermal barrier, increasing the shelter's insulation factor. It is installed between the shelter inner liner fabric and the shelter outer cover fabric (Figure 7).

Figure 7 RBB Installed in a Base-X Shelter

Capabilities

The RBB provides radiant/insulative retardant for conductive, convective, and radiant heat transfer and retards vapor diffusion

[2] RBB is a **<u>Commercial off-the-shelf (COTS)</u>** system produced by HDT Engineered Technologies, *Solon, OH 44139 USA*

through the shelter walls. Constructed with non-toxic and non-carcinogenic materials, the RBB is puncture and tear resistant and does not promote the growth of fungi or bacteria.

NOTE
If the ambient temperature is below -10° F, preheat the RBB with a field heater before setup.

Components

Table 3 summarizes these.

Fits Shelter Size	HDTPart #	Weight	Pack Size (L x W x H)	Pack Volume
103	60103-3RB	55 lbs. 25.0 kg	63 x 13 x 27 " 160 x 33 x 69 cm	12.8 ft^3 0.4 m^3
105	60105-3RB	67 lbs. 30.5 kg	63" x 16" x 30" 160 x 41 x 76 cm	17.5 ft^3 0.5 m^3
203	60203-3RB	68 lbs. 30.9 kg	63" x 17" x 30" 160 x 43 x 76 cm	18.6 ft^3 0.5 m^3
205	60205-3RB	80 lbs. 36.4 kg	63" x 20" x 33" 160 x 51 x 84 cm	24.1 ft^3 0.7 m^3
303	60303-3RB	75 lbs. 34.1 kg	55" x 24" x 32" 140 x 61 x 81 cm	24.4 ft^3 0.7 m^3
305	60305-3RB	110 lbs. 50.0 kg	63" x 35" x 23.5" 160 x 89 x 60 cm	30.0 ft^3 0.8 m^3
307	60307-3RB	138 lbs. 62.7 kg	63" x 39.5" x 28.5" 160 x 100 x 72 cm	41.0 ft^3 1.2 m

Table 3 RBB Components

Operational Principles

The RBB's insulation reduces the Environmental Control Unit (ECU) or heater capacity needed to cool or heat the shelter, reducing the power consumption as well. No additional tools are required for installation and can be deployed by two to three Marines. Once it is installed, it remains in place even during the shelter strike process.

Section 7 – SPACES[3]

Overview

The Solar Portable Alternate Communications Energy System (SPACES) is a portable lightweight battery charger and DC power distribution system. It can use various sources of DC input power, including renewable solar energy.

Capabilities

This system enables Marines to run radios and charge batteries during movements and when occupying stagnant positions. The heart of the system is the **Star Power Module™.** Table 4 summarizes the system's physical and electrical properties.

Parameter	Characteristics
StarPower™ Module Weight	2.6 lb. (1.2 kg)
StarPower™ Module Size	8" (20 cm) x 8" x 1.6" (4.1 cm)
Environmental	MIL-STD-810F
Operating Temp. Range	-4°F (-20°C) to +131°F (+55°C)
Storage Temp. Range -	-59°F (-50°C) to +160°F (+71°C)
Input Voltage Range	9 to 35 VDC
Input Current	14 Amps (max)
Input Power	240 W (typ), 336 W (max)
Output Voltage	12 to 32 VDC w/ Iris Smart Cable
Output Power	160 W per output, 320 W (max)
Efficiency	96% (typ)
Typical BB 2590 Re-Charge Time (Full Sun)	3 hours (typ)

Table 4 Physical and Electrical Properties

[3] SPACES is a **<u>Program of Record (POR)</u>**. For complete Component List, see Marine Corps Stocklist dated May 2011, SL-3-11838A PCN 123 118380 00 TAMCN H001126.

SPACES converts solar and tactical power sources to support 12 volt direct current (VDC) accessories. It supports mixed chemistries and mixed state-of-charge with up to 320 W output.

- Self-contained kit – plug and play – no user controls
- Hard, waterproof kit with foam inserts

Components

SPACES system does not require any special tools. Two Marines can easily assemble and disassemble it in a short time. Figure 8 shows the major elements of SPACES.

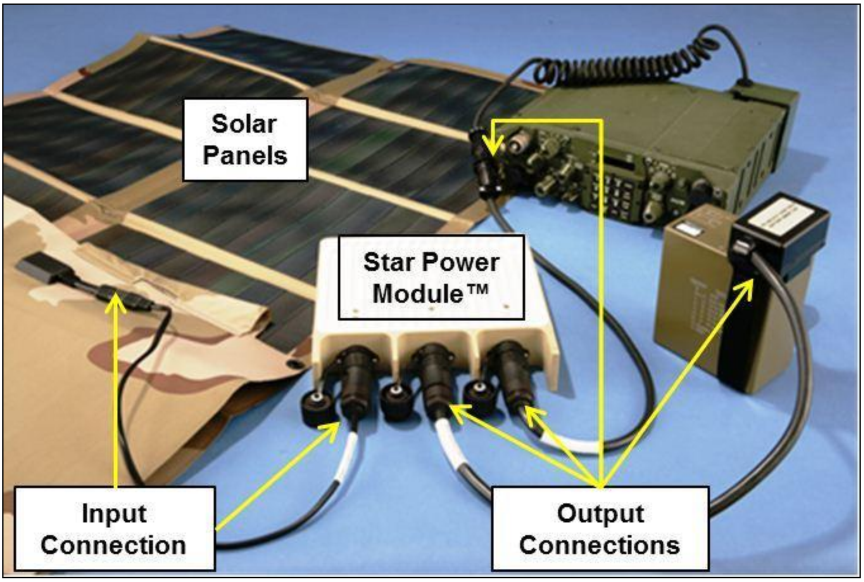

Figure 8 Major Elements of SPACES

Operational Principles

Figure 9 shows various SPACES' operational interfaces.

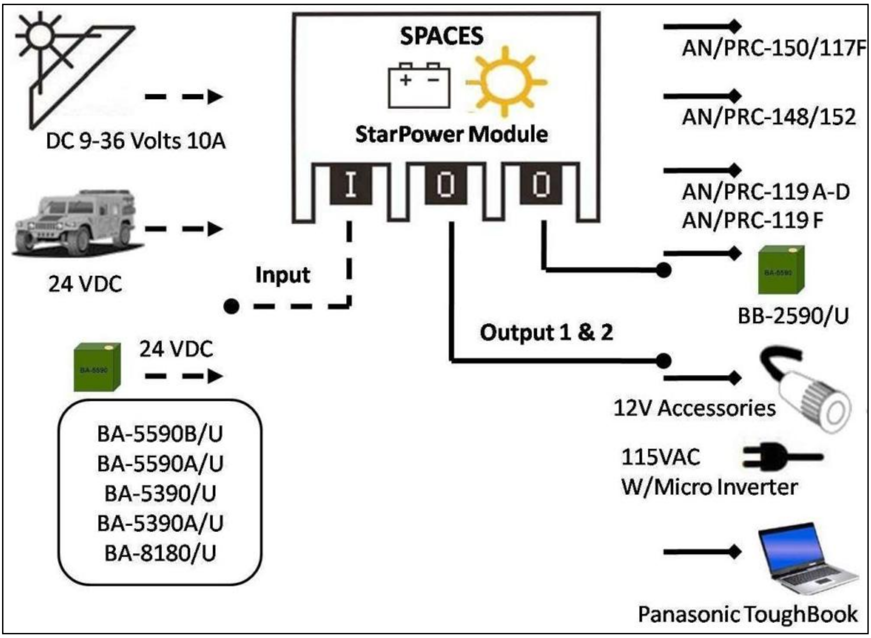

Figure 9 Major Elements of SPACES

Recommended Batteries

The BA-5390, BA-8180 and BB-2590 (rechargeable) are the standard batteries recommended for use with SPACES. However, as provided in TM 11838-OR/2 many other battery types can be used, including the rechargeable BB-390/U, AA, AAA, lead acid batteries, and the operational batteries for the AN/PRC-152 and AN/PRC-153. Whenever possible, rechargeable batteries should be used in conjunction with the SPACES in order to maximize the benefit it provides.

Input Designs / Receiving Power

SPACES uses these three input designs (receiving power):

- **Configuration 1 – Solar**
  - enables charging batteries in any location as long as direct sun light is available
  - the most energy efficient configuration and the primary input source

- first choice; use this design whenever possible

- **<u>Configuration 2 – Battery</u>**
  - enables transfer of stored energy from one battery to another
    - or supplies power to output devices
  - the secondary source of energy
    - used primarily during times of low light / night
- **<u>Configuration 3 – NATO</u>**[4]
  - enables quick, steady source of energy from vehicles through the standard NATO receptacle
  - most reliable source of input
    - requires a vehicle engine to be running
  - use this option when configuration 1 and 2 are not available

---

[4] North Atlantic Treaty Organization – refers to a common receptacle used by all countries in NATO

Section 8 – GREENS[5]

Overview

Ground Renewable Expeditionary Energy System (GREENS) is a modular, portable solar energy conversion and management system that harvests energy from many different sources. It distributes energy using an intelligent management system, and stores excess harvested energy to provide an average continuous output of 300 watts to energize tactical systems needed by Marines at remote Combat Outposts (COP), Patrol Bases (PB), and Observation Posts (OP). It also reduces the need to resupply batteries / fossil fuel for generators.

Capabilities

It can support a variety of mission requirements operating within the 300 watt continuous power generation range (1000 watt peak power). Multiple GREENS systems can be used together to handle higher loads. The system allows Marines to match their expected mission profile with an appropriate GREENS configuration and appropriate accessories.

- Reduces need to resupply batteries / fossil fuel for generators
  - fewer log convoys reduce enemy targeting opportunities
- GREENS is HMMWV and helicopter transportable
- Capacity may be adjusted for mission requirements or transportation constraints:
  - tailored to only what is needed (full, ½, ¼ system)
  - see Table 5 for options

[5] GREENS is a **<u>POR</u>** System. See U.S. Marine Corps Technical Manual TM 12115A-OI dated December 2011 (PCN 500 112150 00) for complete user instructions for the safe installation and operation of GREENS.

Configuration 1	Employs all eight solar panels and all four High Energy Lithium Batteries (HELB) to provide 300 watts for 24 hours or 600 watts for 12 hours.
Configuration 2	Employs four solar panels and two HELB batteries to provide 150 watts for 24 hours or 300 watts for 12 hours.
Configuration 3	Employs two solar panels and two HELB batteries to provide 76 watts for 24 hours or 150 watts for 12 hours.

Table 5 Configurations

Components

Figure 10 GREENS QuadCon Pack up

Two GREENS units are packaged in each designated QuadCon.[6] Once removed from the QuadCon (see Figure 8) it can be set up in about 20 minutes by two Marines and can supply power about 5 minutes after set up.

[6] Quarter size conventional shipping container; i.e., 10 ft. long x 8 ft. wide and 8.5 ft. high; a full container is 40ft long, 8ft wide and 8.5 ft. high.

GREENS is composed of these five major components

Charge Control Box (CCB)

- One (1) each (see Figure 11)
  - regulates and controls GREENS system

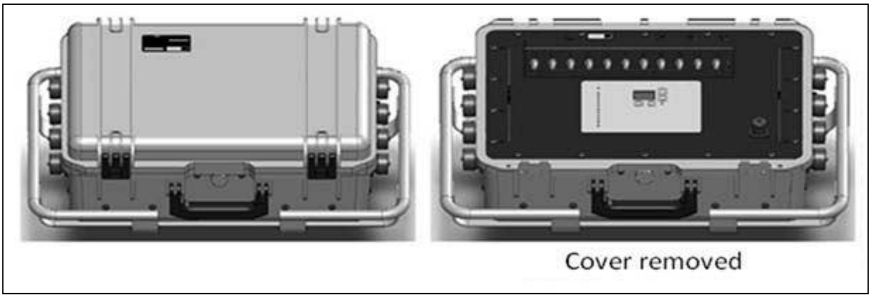

Figure 11 CCB Front View

CCB Capabilities

- Inputs
  - 1000W AC (120V, 60Hz)
  - 1000W DC (24VDC)
  - 2000W Solar
- Output
  - 1000W 28VDC Peak
  - 300W 28VDC Continuous

If too much equipment is plugged in, a breaker will trip and will have to be manually reset.

High Energy Lithium Batteries (HELB)

- Four (4) 25.6 volt, 50 amp-hour $LiFePO_4$ battery packs (Figure 12)
- Intelligent control for charge management and battery protection
- Battery State of Charge (SOC) status is displayed on the top of each case
- Each battery is sealed and contains no user serviceable components

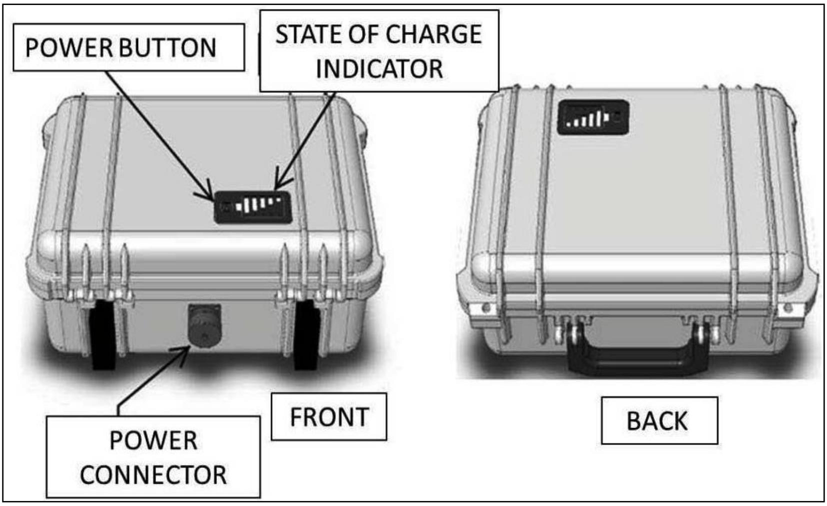

Figure 12 High Energy Lithium Batteries

WARNING
The HELB packs contain lithium cells that if exposed to water may result in a fire and/or explosion. Do not open or crush them.

CAUTION
The controller is designed for charging either the 24 volt high energy lithium battery (provided with greens) or 12 volt lead acid batteries (flooded cell or agm). Connecting any other battery technologies to the controller may result in damage to the CONTROLLER AND/OR BATTERIES.

Integrated Solar Panel Case Assemblies

- Four (4) assemblies – consisting of eight solar panels each
  - see Figure 13

Harness Kit

- Includes all necessary cables for interconnection of the major components
  - also Figure 13

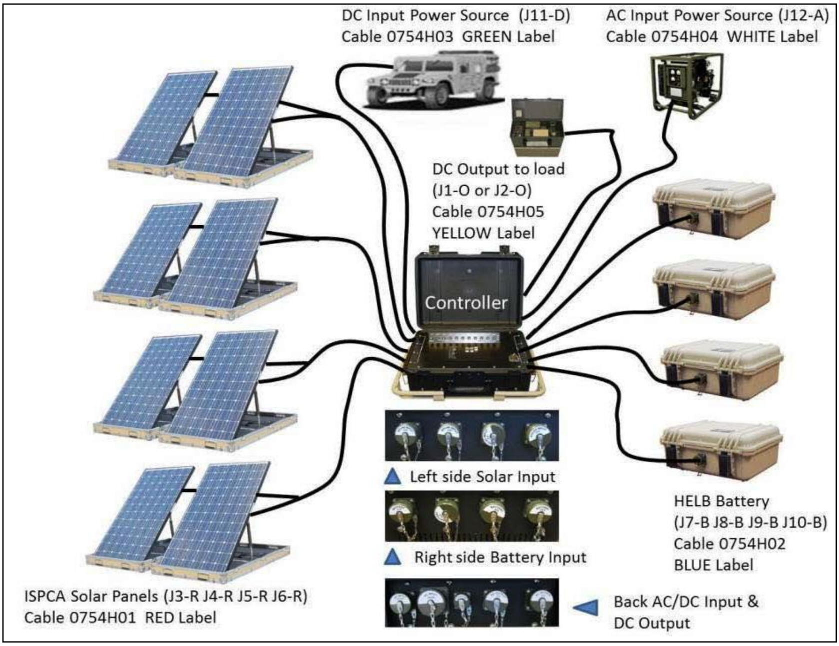

Figure 13 GREENS Interconnect Cables

DC Power Distribution Kit (DC PDK)

The conversion of DC power to AC power using the QP-1800 results in a loss of approximately a 20W. The DC PDK (Figure 14) was designed to allow users to power devices directly from DC power limiting the less efficient use of AC power. The DC PDK contains:

- Two Power Distribution Units (PDU)
- Various cables
  - to distribute DC power to energize laptop computers, radio systems, and to charge various types of batteries

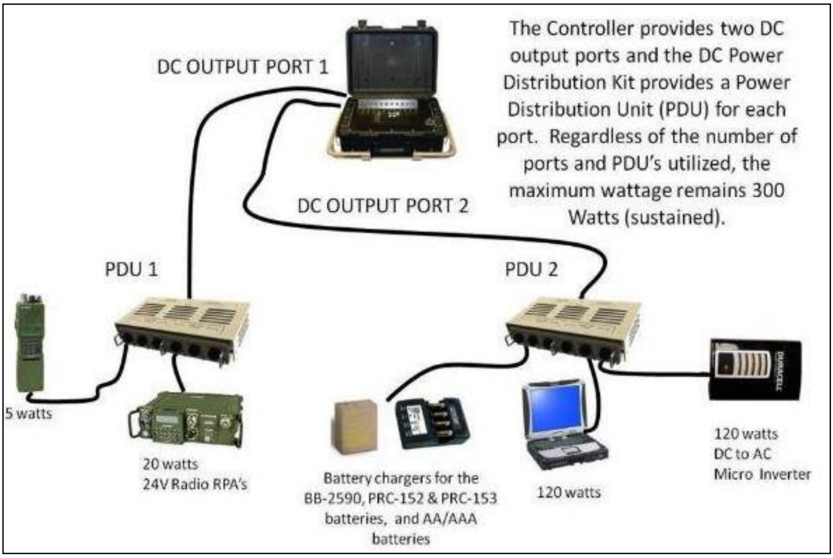

Figure 14 DC Power Distribution Kit

GREENS is also fielded with these two ancillary devices that provide options for users to distribute and use power:

- **<u>Vehicle Mounted Battery Charger (VMBC)</u>** – bulk charger for:
  - AN/PRC-152 and AN/PRC-153 radios
  - AA rechargeable batteries, and BB-2590/U rechargeable batteries
  - J-6520A/U adapter and Supply System Responsible Items (SSRI or Using Unit Responsible Items (UURI)
- **<u>QP-1800 DC to AC Inverter</u>**
  - enables option of operating end item devices directly from AC power

Power Management System

GREENS accepts energy from many different power sources, distributes that energy using an intelligent management system, and stores energy not required for immediate use in batteries for

use when no other power source is available. Figure 15 illustrates this power management system.

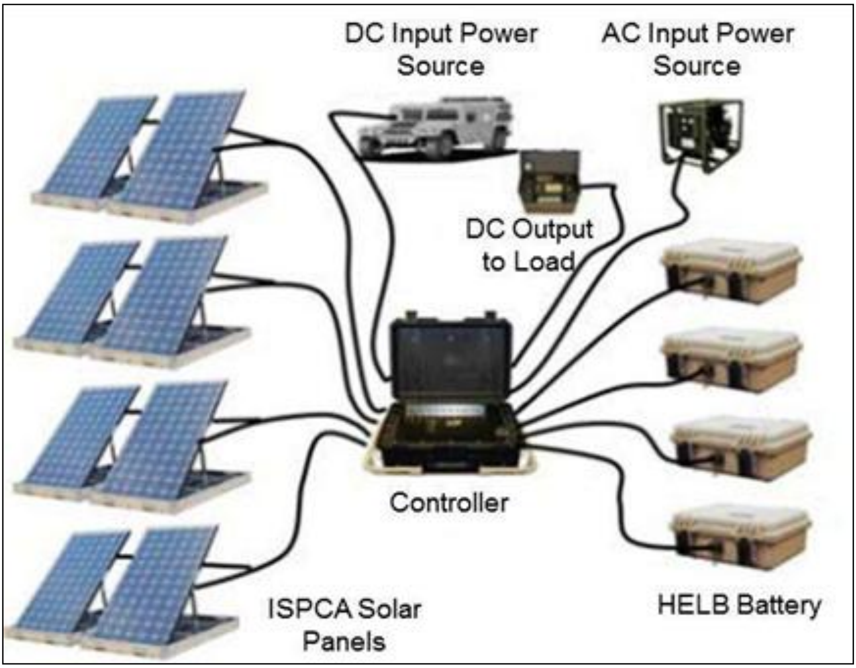

Figure 15 Power Management System

Power Process Nodes

Sustainable power output is directly related to the amount of sunlight striking the face of the panels so ensure each solar panel properly aligned (see Section 2 of this X-File). Nevertheless, solar energy harvesting will not remain constant because cloud cover, rain, and dust can lead to drops in panel/array performance.

It is possible to use too much power during the day. This means the system won't be able to charge the batteries enough to last the night. Operating at loads exceeding 300 watts for extended periods will proportionally reduce the number of operational hours within a 24 hour period.

See Figure 16 for graphic composite of GREENSs process nodes.

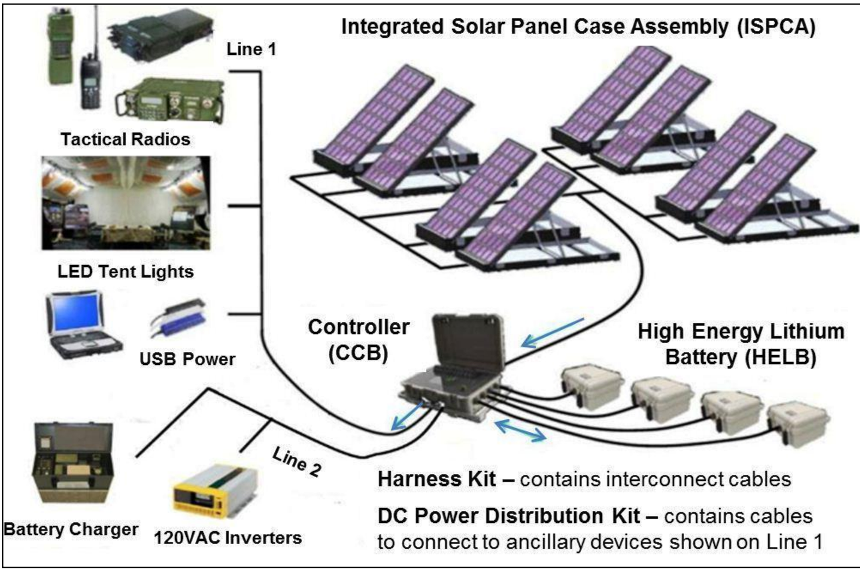

Figure 16 GREENS Process Nodes

Maintenance

Once the system is operational it requires little or no supervision. However, these are essential preventive maintenance actions:

- Inspect all panels daily to prevent excessive dust build up
- Check cables for any abrasions
- Brush off panels (a broom or dry rag will work) every three days
- Wipe down panels once every two weeks
  - do not use chemicals (water only if available)
  - in the desert, wiping off panels with a dry rag works best

CAUTION

In some environments, residue from cleaning materials like glass cleaner can actually attract more dust.

GREENS Supporting HIMARS Employment

The High Mobility Artillery Rocket System (HIMARS) launcher requires continuous 24V power to maintain a mission-ready posture for

- Fire Control System (FCS) and chassis (6 Hawker batteries)
- 2 x PRC-119 radios with VRC-92 vehicle adapter / amp

System is normally powered by the 7.2L truck engine idling for long periods of idling and connecting the Mobile Electric Power (MEP)-501 2kW DC generator set (genset) to the batteries running the FCS. The consequences of this are:

- Vehicle
  - consumption of JP-8 is 0.8 gallons per hour (gph) @idle
  - increased engine wear that reduces its longevity
- Generator
  - consumption of MOGAS is 0.33 gph
  - increased maintenance due to MEP constantly high RPM
  - start/stop wear and tear
  - use of non-USMC equipment/supply

NOTE
The launcher will not fire with inadequate FCS charge.

1 x GREENS system in support of one (1) launcher

- 2 x DC out Cables fitted with NATO female plugs
- 36-hour test conducted by HIMARS battery personnel
- first 18 hours – early afternoon through morning
  - maintained batteries with vehicle and generator cold
- Second 18 hours – normal daily cycle of dry fire missions, mission prep, and maintenance
  - significant periods of haze & cloudy conditions
- GREENS provided adequate power throughout
- Zero failures, low power advisories, or voltage warnings

- See Figure 17

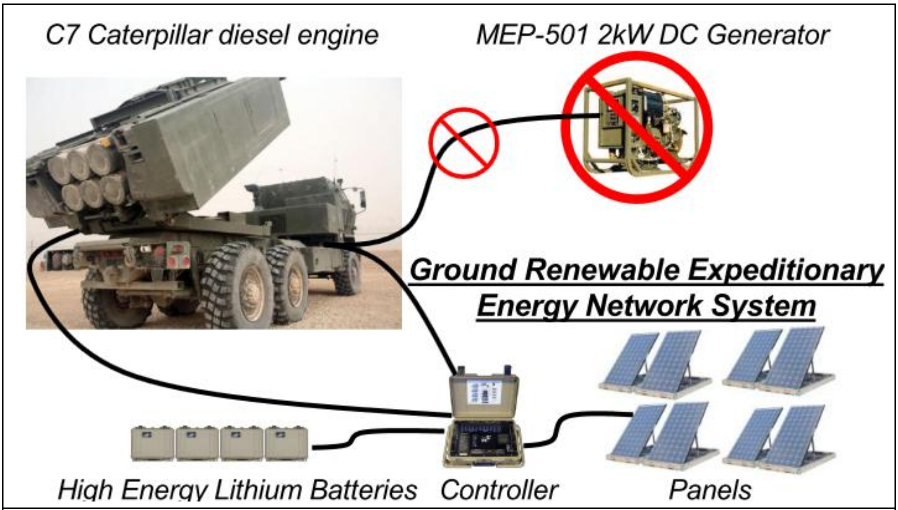

Figure 17 GREENS Supporting HIMARS

HIMARs Setup

- Two NATO plugs
- Two 0754H53-001 GREENS DC output QP1800 cables
- If a NATO plug is not available at the site, use the one out of the QP1800 case that comes with the system
  - this provides the connection for the fire control
- You can also use the NATO plug from the DC input cable
  - but you still will need to take a DC output QP1800 cable from another system
- HIMARS uses one NATO plug into the fire control (Figure 18) and one into the vehicle battery box Figure 19)

Figure 18 an FCS Hookup at the Vehicle

Figure 19 Vehicle Battery Box

When connecting the GREENS to the HIMARS:

- connect the fire control first

- GREENS will see a surge up around 1100 watts
  - Over the next 5 to 8 minutes the power pull will drop to around 290 to 310 watts
- Now connect the vehicle side to the system
  - if the vehicle batteries are low the GREENS will see a large power draw and drop the load

NOTE
The only way to avoid GREENS dropping the load is to have fully charged vehicle batteries before starting

Transportation / Storage

Ensure solar panels are properly stored inside their cases with the issued foam pad between the panels

- Remove any debris from the cases before packaging
- Make sure that the lids to all components are properly closed

NOTE
Primary mode of transportation is inside a QuadCon.

- One QuadCon can hold up to two GREENS units
  - ensures that all the components stay together
  - reduces the risk of damaged gear upon arrival

Alternate modes of transport include the following:

- Pack system components into appropriate vehicle/air platform
- Pack system components into a properly secured trailer

Section 9 – Tactical Shelter Lighting[7]

Overview

The Jameson light emitting diode (LED) shelter lights have these characteristics:

- Durable compact design
- Lightweight flicker free light
- Multi-volt capability 110-230 VAC, 50-60Hz
- Independent pass-through power
- Master controller with individual **On/Off** Switch (Figure 20)

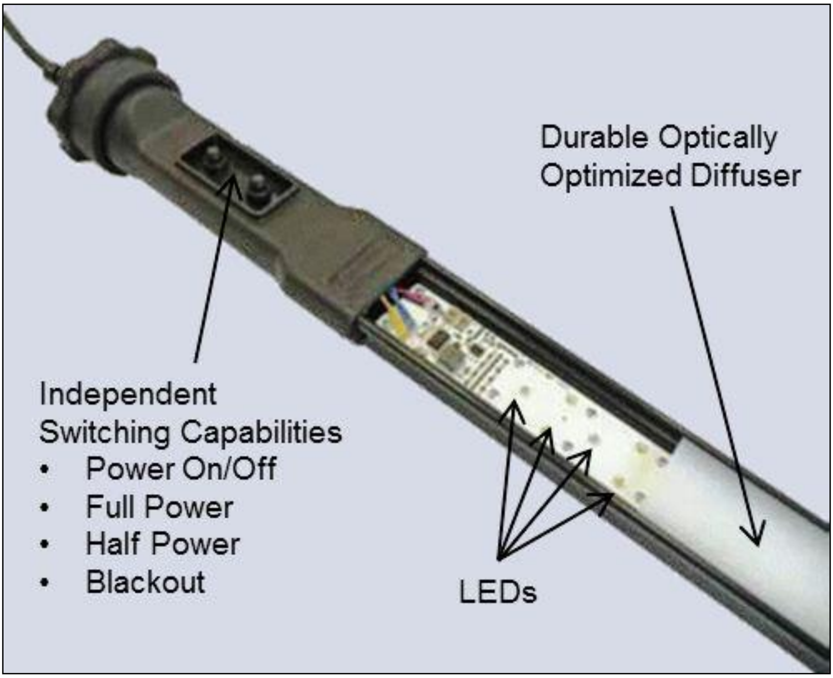

Figure 20 LED Master Controller

[7] Jameson's light emitting diode (LED) shelter lights are a **(COTS)** system.

Capabilities

- Full power
  - full white light illumination
- Half power
  - reduced white light illumination
- Tactical blackout mode
  - can be red or blue illumination
    - see Figure 21

Full Power White Mode Can be dimmed to Half Power for light discipline and power savings	
Tactical Blackout Mode	
Available in Red or Blue	

Figure 21 LED Operating Mode Capabilities

Components

See Table 6.

Overall Length with cords	120”
Body Length without cords	32.25”
Major diameter	3.75”
Minor diameter	2.60”
Weight	4.70 lbs
Cubic Volume	0.06 cu. ft.

Stringable	Yes

Table 6 LED Physical Specifications

Operational Principles

- Universal Voltage Input: 100-240 VAC, 50/60 Hz
  - see Table 7 for system electrical operating specifications

Input Voltage	120			230		
Operating Mode	High	Low	Blackout	High	Low	Blackout
Power (Watt)	27	14	14	27	14	14
Current draw	0.225	0.118	0.118	0.118	0.065	0.081
Lumens	1065	650	440	1065	650	440

Table 7 Electrical Operating Specifications

- Superior hot and cold temperature performance
- Interoperable with Jameson's fluorescent string lights
- Longer life (50,000 hour rating)
- 25-60% lower power consumption than fluorescent bulbs
- Push button dimming and blackout capabilities
- Glare reducing optical design
- Improved strain relief on the connecting wires

CAUTION

- **Do not connect any other devices to this system. They may overload the wiring or circuitry and result in system failure or damage to other devices.**
- **The power supply, master control box and lighting fixtures require ventilation. Enclosing these may cause overheating and circuit failure.**

Appendix A – Acronyms

AC – Alternating Current
Ah – Amp Hour
CCB – Charge Control Box
COC – Combat Operations Center
COTS – Commercial Off-the-Shelf
DC – Direct Current
ECU – Environmental Control Unit
ExFOB – Experimental Forward Operating Base
FOB – Forward operating Base
GREENS – Ground Renewable Expeditionary ENergy System
HELB – High Energy Lithium Batteries
HMMWV – High Mobility Multipurpose Wheel Vehicle
Hz – Hertz
kW – Kilowatt
KWh – Kilowatt-hour
LED – Light Emitting Diode
LiOn – Lithium Ion
MAGTF – Marine Air Ground Task Force
PDK – Power Distribution Kit
PDU – Power Distribution Unit
POR – Program of Record
PV – Photovoltaic
RBB – Radiant Barrier Blanket
SLS – Shelter Lighting System
SPACES – Solar Portable Alternate Comm. Energy System
TM – Technical Manual
VAC — Volts Alternating Current
VDC – Volts Direct Current
VMBC – Vehicle Mounted Battery Charger
W – Watt

Appendix B – Glossary

Alternative Energy – energy derived from non-fossil fuel sources. Alternative energy sources can include wind, solar, geothermal, wave energy, tidal currents, nuclear energy, agricultural residues, bio fuels, and algae.

Azimuth – horizontal direction expressed as the angular distance between the direction of a fixed point and the direction of the object.

Batteries (deep cycle) – a battery that is discharged quickly will not have as much capacity as if it were drained at a slower rate. Most PV system deep cycle batteries are designed for regular discharges of 40 to 80 percent. Battery life depends on how deep the battery is cycled. Drawing deeper into a daily cycle will reduce the overall lifespan of the batteries.

Batteries (effects of temperature) – in 100° (or more) a battery can be expected to have half its normal life; but, its capacity will increase. In colder temperatures (32° or less) a battery may only achieve 60%-80% capacity; but, its total life will increase.

Batteries (primary) – the main sources of power for USMC Corps communications equipment; most notably the Lithium-Sulfur Dioxide battery BA-55908/0. Primary batteries are non-rechargeable, one-time use batteries.

Batteries (rechargeable) – the only option for use with PV systems. Any type of rechargeable may be used, lead-acid and alkaline batteries are most commonly used in solar systems.

Lithium ion batteries are becoming more frequent in solar applications. Deep cycle batteries perform best in PV systems

Battery Capacity –factors affecting battery capacity include battery type, rate of discharge, depth of discharge, temperature, and age of the battery.

Charge controllers – regulate voltage and current from solar panels to adjust for variable solar panel/array output; this ensures batteries are not damaged from overcharging. Some charge controllers protect batteries from being discharged too deeply

Energy – is defined by kilowatt hours (kWh)

Inverters – convert DC output from a battery bank or PV system into alternating current (AC) - AC is the preferred current type for distribution of electricity when more than one load is to be used.

O&M Funds – pays the day-to-day expenses of USMC components in garrison, during exercises, deployments, and military operations.

Photovoltaic (PV) Systems – harvest energy directly from sunlight; e.g., solar panels; PV cells are commonly known as solar cells as they convert sunlight into electrical energy, Photovoltaics can literally be translated as light-electricity[8].

Power – is defined by kilowatts (kWh)

Radiant Barrier Blanket – provides radiant/insulative retardant for conductive, convective, and radiant heat transfer and retards vapor diffusion through the shelter walls.

---

[8] Dept of Energy "Energy Basics" Downloaded on 18 July 2012 http://www.eere.energy.gov/basics/renewable_energy/photovoltaics.html

Renewable Energy – Refers to energy derived from sources that are replenished by a continually occurring process. Energy produced by solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), hydrokinetic, geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project.

Solar Insolation – the amount of solar radiation energy received on a given surface area during a given period of time; typically denoted as Watts per hours per square meter

Solar Irradiance – the total instantaneous power density (solar irradiance) of the sun's rays—on a clear day with the sun rays directly perpendicular to a surface, it is about 1,000 watts per square meter

Tilt Angle – the PV panel's vertical angle relative to the ground. Optimum tilt angle is a function of the sun's elevation relative to the horizon at the location of interest on the earth at any given time. Once a panel aligned to the proper azimuth, the tilt angle is determined. Latitude and time of year are the two factors that determine the optimum tilt angle.